CONSTRUCTION ACROSS NICARAGUA FEASIBLE.

Probably a Report Adverse to the Panama Route.

HARBORS ONE PROBLEM.

With Some Dredging, However, Suitable Channels Can Be Provided.

Street Scene in Managua.

Managua is the capital of Nicaragua, and this view of a scene on the main street will give a good idea of the construction of the city and of the character of its people. The Walker Commission visited this city, and there had interesting interviews with the rulers of the country through which the canal will run.

the Brito promontory and running southeastward. The entrance was 400 feet wide.

An inner harbor was formed by a change in direction of the entrance at nearly a right angle, which gave good protection. The size and depth of the harbor proposed would be utterly inadequate to the present size and draught of ships. A diversion of the Rio Grande to the eastward of the entrance was a necessary feature of this scheme.

Captain Lull's Project.

Captain Lull in his project for a harbor made some changes in the Childs project, with a view to giving a wider entrance and a more capacious and deeper harbor, suited to the increased depth which he proposed.

All the plans proposed have certain inherent defects, and it is scarcely possible to construct a harbor at this place that will be perfect. A breakwater to shelter an entrance becomes a very expensive structure in such a place as Brito, and is liable to introduce other objectionable features.

It is believed, however, that the difficulties of a vessel entering between two jetties that project seaward in the direction of the advancing waves have been overestimated in the case under consideration.

San Juan del Sur is a fairly good harbor, yet its entrance is open to the sea. It is said that no trouble is experienced by shipping at this place from such exposure.

A Pacific Mail steamer calls at this harbor once a week throughout the year. She does not go to a dock, for there is none at which she could lie, but it is understood no trouble is experienced in lightering her from her anchorage.

Will Meet Conditions.

To permit a vessel to enter the harbor normal to the swell and at the same time to guard it against agitation from the admission of large waves are conditions not easily satisfied, but the Commission believes that the form of harbor presented with this report will meet the conditions as nearly as it is practicable to do within the limits of reasonable cost and in a manner less objectionable than any other yet proposed.

This plan is to build a jetty from a point on the beach about 3,600 feet east of the Brito promontory, extending out into the sea in a direction nearly south-southwest to the seven-fathom curve; then excavate a harbor of the form shown on the plan, to the eastward of a north and south line through the root of the jetty, the entrance to be 600 feet wide at the throat.

This will give security and comparatively still water in all winds except those coming from south by west and a few degrees either side. The promontory will protect from winds coming from a more westerly direction, and the jetty from all winds coming from a direction east of south.

Movement of Sand Slight.

The basin to be excavated has a bottom area of about 135 acres and a depth of 30 feet at mean low tide, with a depth of 36 at the entrance. As the movement of sand is slight the cost of maintenance will not be great.

The Rio Grande in this project will not be diverted at its lower end, but it will have to be enlarged in cross section, in order to carry increased discharge.

If the conclusions reached by this Commission that this harbor gives all the protection that is needed be found by time and experience to be incorrect a jetty from the promontory eastward can be added at any future time.

It is believed, however, that such jetty will never be required, and no provision has been made in the estimate for one.

TO CONTROL DRAINAGE AN EASY PROBLEM.

Large Impounding Capacity of the Lake Reduces Dangers of Floods.

To construct safe, durable and stable structures for the control of the drainage and for navigation is a sine qua non.

The principal causes for the failures of dams or reservoirs may be traced to defective foundations, improper design or imperfect construction, single or combined. Probably the most frequent causes of their failure are their permeability, causing a breech by seepage, and their lack of spillway capacity, allowing the dams to be overtopped by floods.

The sites proposed in Nicaragua for the dams are such that in connection with the large impounding capacity of the lake, acting as a reservoir, there is little or no danger of sudden floods reaching their crests, so that the risk from this source is believed to be eliminated by providing an ample waste-way and freeboard.

The Embankment Lines.

This remark applies with still greater force to the embankment lines, which may be used for the purpose of enclosing large artificial lakes in basins of limited drainage area and not subject to the discharge from the river.

Moreover, there is an abundance of material suitable for puddle, which if properly applied will secure impermeability. The main difficulty, therefore, is that resulting from insecure foundations. For the dams in the rivers closing the summit level satisfactory rock bottoms and abutments are available, but to reach rock on the San Francisco embankment line is a more difficult and expensive problem.

The Eastern Division.

In view of the large amount of earth and rock excavation and the necessity for disposing of the spoils, it was decided by the Maritime Canal Company to construct high rock-fill dams on both sides of the lake for the purpose of impounding the waters on the summit level, but the desirability of avoiding the San Carlos River and of facilitating the construction of the dam itself have led this Commission to select a new and better site a short distance above the mouth of the San Carlos River.

The borings made on the site of the proposed Ochoa dam revealed rock at 17 feet below sea level suitable for foundations. The width between banks is relatively narrow, for at an elevation of 100 feet above sea level it is about 1,400 feet.

At this site is below the junction of the San Carlos River, which, at flood stages, it is estimated, may discharge 100,000 cubic feet per second, in addition to the lake and San Juan River drainage, this large volume must either be disposed of over spillways on the San Carlos ridge or be allowed to waste over the dam itself. Its sediment also would be deposited in the bed of the stream above the dam and cause considerable constant shoaling.

At Lower Ochoa.

At lower Ochoa the sand extends to thirty feet below sea level. To avoid these serious objections, as well as to eliminate, if possible, the embankments of the San Francisco and Florida lagoons, examinations were made for a dam site at Tambor Grande island.

The subsequent borings in the bed of the river at this site, however, showed an erosion of the bedrock extending to 128 feet below sea level, which would necessitate a dam in this narrow gorge of the river nearly 250 feet in height, subject to the flow of the entire drainage basin. This project was, therefore, discarded.

The more recent examination and surveys made on the wider reach of the river above the San Carlos gave results which were quite satisfactory. Here the flowage line is almost continuous, requiring but one small embankment, while the section affords ample weir length. Good solid rock foundations exist at about fifteen feet below sea level. Thus the maximum height of the dam from the bottom of the foundation would be 138 feet.

An Objection Avoided.

The construction of a dam at this point avoids the serious objections to the Ochoa site, and also reduces the cost and difficulties of construction.

The estimates are based upon concrete, which can be mixed on the site. Regulating works and sluices can be provided in the original river channel and the entire length of the crest may be utilized for a spillway in case of necessity.

The typical section on which the estimates are based is the ogee rising from the natural bed of the stream at an elevation of about thirty-eight feet above the sea level to the proposed weir still at ninety-eight, with regulating sluices to control the higher stages. The width of the base at the deepest point is 100 feet. The ordinary stage of water at the foot of the dam is about fifty-five above sea level, while extreme low water is about forty-five.

Sites for Low Dams.

There are various locations on the river where dams may safely be placed for variations of project. Taking these in order, coming down stream, the first may be at Castillo, where the river flows over ledges of basalt, which is somewhat jointed, giving it the appearance of being stratified, but it is believed to be firm and strong. The anchorages also are good.

At Upper Machuca, three miles above Machuca, the rock is calcareous sandstone, with limited weathering. Solid rock is usually found under a few feet of sand in the river channel, but the rock in the adjacent hills is weathered down nearly to the same level as the surface of the solid rock in the channel, so that the anchorage must be in residual clay and soft rock.

The Machuca site is situated across the head of the Campana island. It is based on fine-grained, light bluish gray rock, evenly bedded, and closely resembling a fine-grained quartzite. The borings on the south banks, however, show great depth of weathering, making it desirable to shift the location further up or down stream.

Conchuda, about two miles above the Boca San Carlos, also affords a possible dam site and has been considered with a view to reduce the large amount of rock excavation incidental to the Machuca dam projects.

The Relative Cost.

These estimates are based upon the same prices in each case and are submitted merely as a guide to the relative merits of the plans:

Low dam at Upper Machuca	$1,045,569	
Low dam at Lower Machuca	806,040	Crest 86.6
Low dam at Boca San Carlos	2,633,124	
	$4,544,733	
Low dam at Lower Machuca	$1,240,785	
Low dam at Conchuda	2,721,411	Crest 110
Low dam at Boca San Carlos	2,633,124	
	$6,595,320	

Both of the above schemes would require, in addition, a large amount of rock excavation in the river to create navigable channels in the pools which would be avoided by the higher single dam.

Southeastern Hills.

The hills to the southeast of the San Carlos River contain depressions which would have to be closed by earthen embankments to provide for the Menocal project, with weirs through the saddles.

The depth to hard rock varies from probably 60 to 100 feet, but as the San Carlos embankments will be avoided by the change of the dam site to a point above the Boca San Carlos, no further discussion of its embankment line is required. It would be necessary, however, to extend the San Francisco embankment lines from Ochoa up to the left bank of the river to connect with this new location, involving heavy work.

To ascertain the character of the material underlying the proposed embankments crossing the Florida, San Francisco, Nicholson and Chanchos depressions, deep borings were made in each, which revealed the residual clay and soft rock beneath the alluvium, but in thinner strata than on the hills.

The rock is only moderately hard, consisting chiefly of talcose volcanic stuff, with a thin bed of earthy limestone. The silt in these depressions and swamps apparently extends to about ten feet below sea level, and renders it desirable to reduce the height of the embankments as much as possible.

All Routes on Left Bank.

All the routes traverse the reach on the left bank of the San Juan from Boca San Carlos to the San Francisco near its mouth, and hence cross these lateral tributaries, but at different elevations, dependent upon the number and location of the locks.

Much has been said pro and con concerning the possibility of constructing a dam at La Flor site, and the board of 1895, basing its conclusions upon certain exhibits as to geological structure, declared it inexpedient, in view of the slight advantages and the ability to construct a canalized channel at a somewhat greater cost on the left bank of the Rio Grande.

In the light of more recent borings and their interpretation by Dr. Hayes, this commission is of opinion that a dam at this point is practicable.

End at Bueno Retiro.

The summit level would terminate at Bueno Retiro, about nine miles from the lake, where the topography is well adapted for the purpose, as it affords opportunities for spillways directly into the bed of the Rio Grande and Guachipilin and a good lock site. Here a small ovoidal hill rises from the bottom of the valley, "composed of a calcareous shale, more or less disintegrated, but sufficiently firm for foundation purposes."

The rock is about fifty feet above sea level, and comparatively little silt would have to be excavated to place the foundations. The regulating works with the lock will close the summit level, making it unnecessary to build a dam at this site.

No other dams are required on the west side under any of the variants.

SIX LOCKS IN THE ROUTE SELECTED.

They Will Have a Lift of from 18.41 to 20 Feet, and Will Cost Seventeen Millions.

On the route selected as a basis for the estimate, it is proposed to construct six locks of 18.41 feet lift each on the eastern division, giving a total of 110.46 feet, and four locks of 29 feet lift each on the western division, giving a total of 116 feet, the difference of 5.51 feet being due to the difference in rise of tides in the two oceans.

In estimating the cost of the locks, the large Poe lock at the Sault Ste. Marie Canal, at the outlet of Lake Superior, was taken as a standard, and the dimensions of lock chamber, fore and tail bays, gates, culverts, etc., were modified to adapt them to the present requirements.

The lock pits were extended to 15 feet below the floor to provide for the culverts and valves and the necessary foundations.

Table of Dimensions.

The following are the dimensions used for one of the 18.41 feet lift locks:

Number of culverts	4
Length of floor and side walls	939.5 ft.
Width of floor in the clear	80 ft.
Height of side walls, lift, draught 4 ft.	52.41 ft.
Length of sides between abutments	60.45 ft.
Width of side walls at top	10.00 ft.
Width of side walls at bottom	21.53 ft.
Width of abutment walls at quoins	31.77 ft.

On the western division the topography is such that the best results are obtained by the use of four locks having the same dimensions as to length and breadth, the only modification being in the lift and thickness of the walls and foundations.

Upon this basis the six locks on the eastern division will cost.. $9,560,400
The four locks on the western division will cost 7,412,580

Making the total cost $16,972,980

The general advantages and disadvantages the several locations have already been stated under the head of "Projects and Routes," but no final location nor estimate could be completed until after the quantities of the different classes of material on the several routes had been determined.

As a large number of variants are possible, particularly on that part of the route lying between Poca San Carlos and the sea, and as it was impossible to determine before the preliminary surveys were completed and plotted which would give promise of the best results, the detailed geological examination by borings on any specific route had to be deferred for a later date.

The classification which has been made along these low level routes is, therefore, based upon outcrops, borings by the canal company, confirmed by the commission at a few points, and an examination of the region, which is believed to be ample for the purpose of an estimate.

Reliable Computations.

The collection, plotting and computing of these data have required considerable time, but so far as quantities are concerned, they are quite reliable. There may be variations in the classification where the lines of separation between different materials merge into one another, but they will be more or less equalized, so that errors due to this cause will be small.

For more convenient reference and comparison of the quantities under the variations of line and grade, they have been arranged in a table, which gives the amount of excavation and embankment in each division, and for each project and class of material, excepting for the harbors, railroad and dams. The cost of the dams, locks, weirs and other structures is given in the item entitled "Auxiliary Cost," appended to each division.

By the aid of this tabular statement of quantities an estimate of the cost of constructing the canal trunk may readily be obtained by applying any suitable unit price to the factors as stated.

Amount of Dredging.

The amount of dredging for the two harbors not included in the table, which should be added to the totals is, for Greytown, 10,748,900 cubic yards, and for Brito 9,500,000 cubic yards. The jetty and other harbor work is not included in the table, but is stated in the estimates.

For the route recommended by the commission, passing to the north side of Silico Lake, following the left bank of the San Juan and Rio Grande rivers, and having a bottom width of 150 feet, with ten locks and one dam, the quantities from ocean to ocean, exclusive of the railroad, are:

	Cubic yards.
Dredging, river and coastal plain	61,738,842
Dredging, lake and harbors	37,557,750
Earth excavation and embankment	29,907,966
Disintegrated rock	15,248,312
Solid rock	7,575,092
Rock under water	734,872
	152,781,270

FIGURING ON THE TOTAL COST OF IT.

Few Standards for Comparison Exist, but the Chicago Canal Is Taken as a Criterion.

The Commission has endeavored to reach conclusions in respect to the probable cost of the canal that will be fair and just. It has tried to have the figures represent the probable cost of the canal as nearly as can be ascertained, without being too high or too low.

It must be admitted, however, that any estimate of probable cost is to some extent a matter of judgment. It is not possible to determine this matter with absolute certainty, as many of the elements on which one's judgment would be based are not accurately known. One's experience in like work and the experience of others are the only guides.

The work on the Panama Canal would, perhaps, come near it in some respects, but no one would think of comparing the extravagant methods which characterized the early history of that enterprise with the methods that should be employed in this.

The Chicago Canal.

The latest work of magnitude of this character which affords to some degree a means of comparison is the Chicago drainage canal. The total excavation for this work amounted to about 12,318,000 cubic yards of rock, and 26,087,000 cubic yards of earth, a total of 38,405,000, of which about 10 per cent was dredging.

The earth in the Nicaragua Canal varies in character from stiff indurated clay to diluted silt. The range is equally wide in the Chicago drainage canal. It cannot be asserted that the earth is alike in the two places, but it is believed that it may be substantially so. Under such circumstances it might be fairly assumed that the average cost of earth excavation, if the canal were located near Chicago, would be 29 cents.

As the Chicago drainage canal affords the nearest precedent available, and as the actual average prices of that work have been taken as a basis, it is necessary to state the classification of the material as specified for that work, which was as follows:

"For the purpose of letting the contracts the material to be excavated was divided into two classes, rock and 'glacial drift.' The first term explains itself, but the character of the material termed 'glacial drift,' this being an entirely arbitrary classification, needs some further explanation.

The Nicaragua Rock.

In Nicaragua the rock on the western division is chiefly a calcareous shale, thinly stratified and much broken. Some pits of considerable depth have been excavated without blasting, and the rock has been used for macadamizing the roads. It is believed that a large part of this rock could be excavated with steam shovels without blasting.

It is drilled slightly easier than the Chicago limestone, and is more brittle. The location of the spoil banks would be quite similar to that of the Chicago work.

Between Lake Nicaragua and the Caribbean Sea, viz., the eastern division, the rock is basalt, dacite, sandstone and volcanic stuff. The basalt and dacite are both considerably harder to drill and blast than the Chicago limestone. In the larger cuts the waste material will have to be transported some distance to the dumping grounds.

PRICES OF DIGGING FOR RAILROAD WORK.

It Gives an Opportunity to the Engineers to Estimate on Canal Making.

William H. Keith, contractor, reports the cost of work on the National Railway of Costa Rica to be for solid rock, 60 cents in gold per cubic yard, for loose rock 30 cents in gold per cubic yard, and dry earth 18 cents in gold per cubic yard; concrete in place, including "forms," $9 per cubic yard.

Louis Wichmann, general manager of the Atlas Company, who has been engaged in building a railroad from Greytown to the lower San Juan River, stated "that the total cost per cubic yard of excavation on the Silico Railroad is $1.25 Nicaraguan currency, equal to 50 cents in gold.

In explanation of this abnormally high price, he says that "the disadvantages were extremely bad weather, especially in June and July, during which time we had some seven weeks of continuous rain, and the principal part of the material being heavy clay it was very difficult to handle.

"The material on the first big through cut at the Silico end consisted of conglomerate, with large round boulders, which could only be removed after blasting, and, unfortunately, owing to the American-Spanish war, we were unable to secure explosives at the time when they were most needed."

Their Difficulties Not Ours.

Other difficulties mentioned were the long carriage to the spoil banks and the fact that all supplies, tools and provisions had to be transported on the backs of laborers.

These conditions and prices cannot, therefore, be cited as being comparable to the probable cost of so great a work as the construction of this canal, where the most modern appliances should be used.

Quite recently it is credibly stated that this railroad had cost more than was anticipated, and that the total cost was from $110,000 to $120,000, length 6¼ miles, equivalent to from $16,923 to $18,461 per mile, and that this cost included everything—roadbed, rails, rolling stock, bodegas, wharves and all terminal facilities at both ends.

The Silico Railroad.

The length of the Silico Railroad is six miles and a half. The cost of excavation varied from 50 cents to $1 (Nicaraguan currency) per cubic yard, depending upon the condition of the weather and the labor. During the early part of the construction Fortune Island negroes were employed, but were found unsuitable for the work. While these men were employed the cost of excavation was rather high. The labor now consists of natives and Jamaicans, and the cost of excavation is kept below 70 cents.

The cost of food for each man per day varied from 52 cents to 75 cents. This is included in the cost of excavation. The material chiefly excavated was blue and brown clay. In handling the blue clay the rains had no effect upon it whatever. The brown clay becomes rather difficult to shovel when wet, as it has a tendency to stick. In the former the same amount of material can be hauled on a wet day as on a dry day. The haul in some cases was over four hund feet. During rainy days the work was not interrupted.

FIVE PER CENT MORE THAN AMERICAN PRICES.

So Says Engineer T. P. Roberts in His Report on Cost of Construction.

Colonel T. P. Roberts, chief engineer Monongahela Improvement, reports:

"On the Nicaragua Canal, if extra good prices are paid foremen and bosses, the actual cost of work will not come much in excess of that for which it could be done here. A general increase of 5 per cent over American prices ought to be sufficient.

"Physicians and sanitary engineers should be employed to select the places for camps, provide the water supply and look after drainage. If this be properly done, the cost for hospital service would not be great. I do not see why this item should be differentiated. * * * * A mileage tax on all salaries and wages should be fixed to maintain hospitals.

"It has been my observation for several years past that American engineers have been overestimating the cost of work. They appear to me to not fully realize the wonderful improvements which have been made in this country.

"Many of them still think that French and German methods on canal work admit of little improvement, but such engineers have not been attentive students of the Chicago drainage canal experience.

Average Prices Increased.

In view, however, of the difficulties of securing a sufficient supply of laborers for so great a work, and of regulating their wages, the Commission has concluded to increase the actual average prices paid at Chicago by 33 1-3 per cent for all earth and rock work on the western division, and by 50 per cent for work on the eastern division, after allowing an increase of 10 cents for rock on the eastern div s on, because of local differences and charac.er of material.

The prices applied to the quantities will therefore be as follows:

On the East Side.

For Greytown Harbor, dredging	$0.25 per cu. yd.
For Greytown Harbor, jetties	2.50 per cu. yd.
For dry earth excavation	.44 per cu. yd.
For solid rock excavation	1.80 per cu. yd.
For dredging in upper river	.30 per cu. yd.
For dredging in lake	.20 per cu. yd.
For rock under water	5.00 per cu. yd.
Timber cribs	3.25 per cu. yd.
Clay puddle and back filling, exclusive of cost of excavation	.50 per cu. yd.
Concrete in structures other than locks	8.30 per cu. yd.
Concrete in locks	7.23 per cu. yd.
Stone pitching on embankments	2.00 per sq. yd.
Timber in structures	60.00 B. M.
Clearing	75.00 per acre.
Clearing and grubbing	100.00 per acre.

On the West Side.

For dry earth excavation	$0.33 per cu. yd.
For solid rock excavation	1.03 per cu. yd.
For dredging harbor	.20 per cu. yd.
For rock under water	5.00 per cu. yd.
For jetties	2.00 per cu. yd.
Timber cribs	3.00 per cu. yd.
Clay puddle and back filling, exclusive of cost of excavation	.50 per cu yd.
Concrete in structures other than locks	8.30 per cu. yd.
Concrete in docks	7.23 per cu yd.
Stone pitching on embankments	1.75 per sq. yd.
Timber in structures	60.00 B. M.
Clearing	75.00 per acre.
Clearing and grubbing	100.00 per acre.

The prices for structural work of locks and weirs are based on the cost of similar work in the United States, to which 33 per cent has been added for difference of location, including climate, etc.